APPENDIX C

LABORATORY MEASUREMENT OF BER

In this Appendix, the laboratory procedure to determine Bit Error Ratio (BER) is defined.

C.1. Test Procedure

(R) To perform the test, two transceivers are required, one for each end of a test loop, as shown in Figure C-1. (See Figure D-1 of Appendix D for a description of the test loops.) The implementation of the transceiver **shall** include any system components that would be part of the transmission path (e.g. line interface circuits and protection circuits). Access to the transmitted and received customer data (B and D channels) and to the tip-ring port of the DSL **shall** be provided as specified in TR-NWT-000397[3].

(R) A pseudo-random binary source (PRBS) test signal (binary sequence) **shall** be applied at point A and received at point B. Another PRBS **shall** be applied at point C to create realistic echo conditions for the receiver at that end. No pattern receiver is required at point D because only one direction is under test at one time.

(R) Initially, point F **shall** be on a transceiver controlled by an independent external clock signal; point E **shall** be on a transceiver that derives timing from the received signal. When these tests are performed in a laboratory, the test loops are likely to be assembled from pairs on cable reels with both ends of the pair appearing in the same laboratory. The tests **shall** be performed with no connections other than the test loop between the two transceivers. The loops for testing received signal performance, numbered 1 through 15 in Figure D-1, are individually inserted between points F and E in Figure C-1. In addition, the tests described **shall** be performed on a "zero-length" loop, i.e., with the LT connect to the NT through a pair of wires of length no greater than 10 feet (3 meters). The test **shall** be repeated for each direction on each test loop; that is, point F (Figure C-1) at the end labeled LT (Figure D-1) and point E at the end labeled NT, and then again with point F at the end labeled NT and Point E at the end labeled LT. All the tests described **shall** then be repeated with point E on a transceiver controlled by an independent external clock signal; point F **shall** then be on a transceiver that derives timing from the received signal.

C.1.1 Simulated Crosstalk

Simulated crosstalk is introduced at point E in Figure C-1 by applying a calibrated filtered Gaussian white noise source to the receiver input terminals. The noise source is frequency-shaped and its level set to simulate near end crosstalk (NEXT) from 49 disturbers in a binder group. The assumed power spectral density (PSD) of these disturbers is greater at high frequencies (above 50 kHz) than any 2B1Q signal that meets the standard.
After application of a simplified NEXT model to the assumed PSD of the disturbers, one obtains the PSD of the NEXT, given in the equation below as P_{NEXT}, as plotted in Figure C-2.

$$P_{NEXT} = \left[K \times \frac{1}{f_o} \times \frac{\left[\sin\left(\frac{\pi f}{f_o}\right)\right]^2}{\left(\frac{\pi f}{f_o}\right)^2} + K \times \frac{2}{2f_o} \times \frac{\left[\sin\left(\frac{\pi f}{2f_o}\right)\right]^2}{\left(\frac{\pi f}{2f_o}\right)^2}\right] \times \frac{f^{\frac{3}{2}}}{1.134 \times 10^{13}}$$

where

f = frequency in Hz

f_o = 80,000 Hz

$K = \frac{5}{9} \times \frac{V_p^2}{R}$

V_p = 2.33 Volts

R = 135 Ohms.

The equation and the figure are single sided PSDs, meaning that the integral of P_{NEXT}, with respect to f, from 0 to ∞, gives the power in Watts.

The simplified NEXT model has decreasing loss with a constant slope of 15 dB per decade of frequency, and 57 dB loss at 80 kHz. See Section 4.1 for a discussion of crosstalk.

Note that P_{NEXT} has a significant amount of power in its 160 to 320 kHz lobe, and continues to have significant power in successive lobes above that. However, a bandlimiting filter may be used to sharply limit the PSD at frequencies above 320 kHz.

(R) The simulated crosstalk **shall** be applied in such a way as to achieve the appropriate voltage level without disturbing the impedance of the cable or the transceiver.

C.1.1.1 Calibration of Crosstalk Simulation Filter

(R) To set the simulated NEXT at the reference level (also called the point of 0 margin) the simulated NEXT must have the power and PSD implied by the equation for P_{NEXT}. However, the accuracy obtained will depend on the design of the filter used to create the simulated crosstalk. The greatest accuracy is required at the highest points of the P_{NEXT} function. In the band 0 to 320 kHz, the highest point is at approximately 50 kHz, and a second peak occurs at approximately 220 kHz. The value of P_{NEXT} is approximately -95.9 dBm/Hz at 50 kHz. The accuracy of the PSD obtained must be ±1 dB at all values of PSD between the peak, -95.9 dBm/Hz, and -106 dBm/Hz. This is the case approximately over the two frequency ranges 8 to 145 kHz, and 175 to 300 kHz. Elsewhere, the accuracy **shall** be ±3 dB. At the notches (160 kHz and 320 kHz), the upper bound never goes below -113 dBm/Hz, and the lower bound is absent in the same frequency ranges. To allow for the bandlimiting filter, there is no lower bound at frequencies higher than 270 kHz. Some of the tolerance limits are plotted in Figure C-2 in order to illustrate the tolerance requirements.

The integral of the P_{NEXT} function over the limits 0 to 320 kHz is -44.2 dBm. However, the total power in the simulated crosstalk should take into account the effects of the bandlimiting filter. The theoretical value of the total simulated NEXT power should be re-computed after P_{NEXT} is multiplied by the transfer function of the bandlimiting filter used.

The total power of the simulated NEXT **shall** be within ±0.1 dB of the theoretical value computed as indicated.

C.1.1.2 Measurement of Simulated NEXT Power and PSD

(R) The PSD of the simulated NEXT, and its average power, **shall** be measured at the output of a voltage source of between 4000 Ohms to 6000 Ohms Thevenin impedance, terminated in a load consisting of a parallel combination of 135 Ohms and Z_c, the network shown in Figure C-3. The power dissipated in the 135 Ohms resistor represents the power at the receiver input; thus the NEXT power is the power dissipated in this resistor. Z_c is a complex load and the calibration mechanism must ensure that the required simulated crosstalk PSD, P_{NEXT}, is coupled into the 135 ohm resistor within limits specified in Figure C-2.

C.1.2 Longitudinal Noise

Noise simulating longitudinal power line induction (60 Hz and associated harmonics) **shall** also be introduced at point E in Figure C-1. The method of introducing the longitudinal noise, and the amplitude and waveform of the induced signal **shall** be as follows:

(R) For the loop under test an induction-type neutralizing transformer **shall** be used to inductively couple longitudinal voltage/current to the loop. The loop make-up should be maintained by accounting for the length and gauge characteristics of the transformer. The neutralizing transformer **shall** be inserted at 50% ± 10% of the distance from the network side (The end labeled LT in Figure D-1).

(R) A sawtooth longitudinal voltage waveform **shall** be used because it has a harmonic content similar to power line induction (Figure C-4). The applied voltage **shall** be 50 Volts RMS.

(R) If desired, the test may be run with a low impedance longitudinal termination on the network side (the end labeled LT in Figure D-1). For that case, the longitudinal termination **shall** be adjusted so that the longitudinal short circuit current in the termination is at least 3.6 mA RMS.

C.1.3 Power-Related Metallic Noise

(R) Noise simulating power line induction (60 Hz and associated harmonics) **shall** also be introduced at point E in Figure C-1. The harmonics **shall** be coupled to the line via a high-impedance coupling circuit (J in Figure C-1). The noise test **shall** be conducted with all combinations of two of the harmonics listed below at the power level indicated:

Frequency (Hz)	Tone Power (dBm into 135 Ohms)
60	-47
180	-49
300	-59
420	-65
540	-70
660	-74

C.1.4 Procedure

(R) BER measurements may be performed on one or more sub-channels (e.g., B, 2B, or 2B+D). B or D channels not used for BER measurements **shall** also be driven by a PRBS. The averaging time for determination of error rate **shall** be at least 10 minutes when the bit stream under test is 144 kb/s or more, at least 13 minutes when the bit stream is 128 kb/s and at least 25 minutes when the bit stream under test is only 64 kb/s. For each test loop, and for each direction of transmission, the measurement procedure **shall** be as follows:

(R) BER is tested with noise applied at Point E. The noise applied at point E includes simulated NEXT, longitudinally induced voltage and power-line-related noise. Jitter, as specified in 5.5, must also be present. The attenuator G in Figure C-1 **shall** be set so that the power spectral density of the resulting simulated NEXT on the line is greater, by a margin specified below, than the calculated power spectral density P_{NEXT}.

C.2. Margin

(R) Satisfactory performance **shall** be obtained, as described in 5.2.1.2, with a margin of at least 6 dB with the null loop and with test loops 4-15, listed in Figure D-1.

(O) Satisfactory performance **should** be obtained with a margin of at least 0dB with test loops 1-3.

NOTE: Consistent with 5.2.1, during an interim period until 1992, a corresponding reduction in margin is allowed for performance tests of transceivers receiving signals from transmitters with reduced nominal pulse amplitude. For instance, when the transmitter has a 2.0 nominal pulse amplitude, the margin at the receiver is reduced by 2.0 dB. The reduction in margin is applied to all test loops. The level of the simulated NEXT described in C.1 applies to all transceivers.

C.3. Notes on Test Procedure for Measuring BER

The filter needed to simulate the crosstalk interference from 49 disturbers can be conceptually divided into three sections: one that is shaped like the power spectral density (PSD) of an assumed interferer; one representing a model for NEXT characteristics for 49 disturbers; and one that bandlimits the simulated crosstalk at four times the baud rate of the 2B1Q system (320 kHz). The design of the filter in not considered here. Requirements to assure sufficient accuracy of the resulting simulated NEXT are given in Section C.1.1.1.

Figure C-5 shows PSD of the assumed interferers, the basis of the first conceptual section, and is expressed as P in the following equation:

$$P = K \times \frac{1}{f_o} \times \frac{[\sin(\frac{\pi f}{f_o})]^2}{(\frac{\pi f}{f_o})^2} + K \times \frac{2}{2f_o} \times \frac{[\sin(\frac{\pi f}{2f_o})]^2}{(\frac{\pi f}{2f_o})^2}$$

where

f = frequency in Hz

f_o = 80,000Hz

$K = \frac{5}{9} \times \frac{V_p^2}{R}$

V_p = 2.33Volts

R = 135 Ohms.

The equation and the figure are single-sided PSDs, meaning that the integral of P, with respect to f, from 0 to infinity, gives the power in Watts.

The first term in the equation for P is *half* of the PSD of an 80 kbaud 2B1Q signal with random equiprobable levels, full-baud square-topped pulses and no filtering (10.5 dBm). The second term is the PSD of a similar signal of twice the baud rate (13.5 dBm).

To complete our understanding of the assumed interferer, consider P_1 given in Figure C-5 and in the following equation:

$$P_1 = K \times \frac{2}{f_o} \times \frac{[\sin(\frac{\pi f}{f_o})]^2}{(\frac{\pi f}{f_o})^2}$$

where

f = frequency in Hz

f_o = 80,000Hz

$K = \frac{5}{9} \times \frac{V_p^2}{R}$

V_p = 2.33Volts

R = 135 Ohms.

P_1 is the *full* PSD of an 80 kbaud 2B1Q signal with random equiprobable levels, full-baud square-topped pulses, and no filtering (13.5 dBm). P_1 has the property that it is essentially identical to the PSD of most 2B1Q systems at frequencies below 50 kHz, but because there is no pulse shaping (filtering) it is greater than the PSD of most 2B1Q systems at frequencies above 50 kHz, and in fact it violates the upper bound for PSD (Figure 5-3).

P is nearly identical to P_1 at frequencies below 50 kHz, but the second term causes the null in P_1 at 80 kHz to be filled in. Selection of P to represent the interferers is a deliberate attempt to force designers to sharply reduce the sensitivity of their receivers to interference components above 50 kHz. Because P has essentially the same value below 50 kHz as a transceiver meeting the standard, the margin should be the same as is achieved using the transceiver's own PSD as the basis for producing simulated crosstalk, as long as the the receiver is properly filtered.

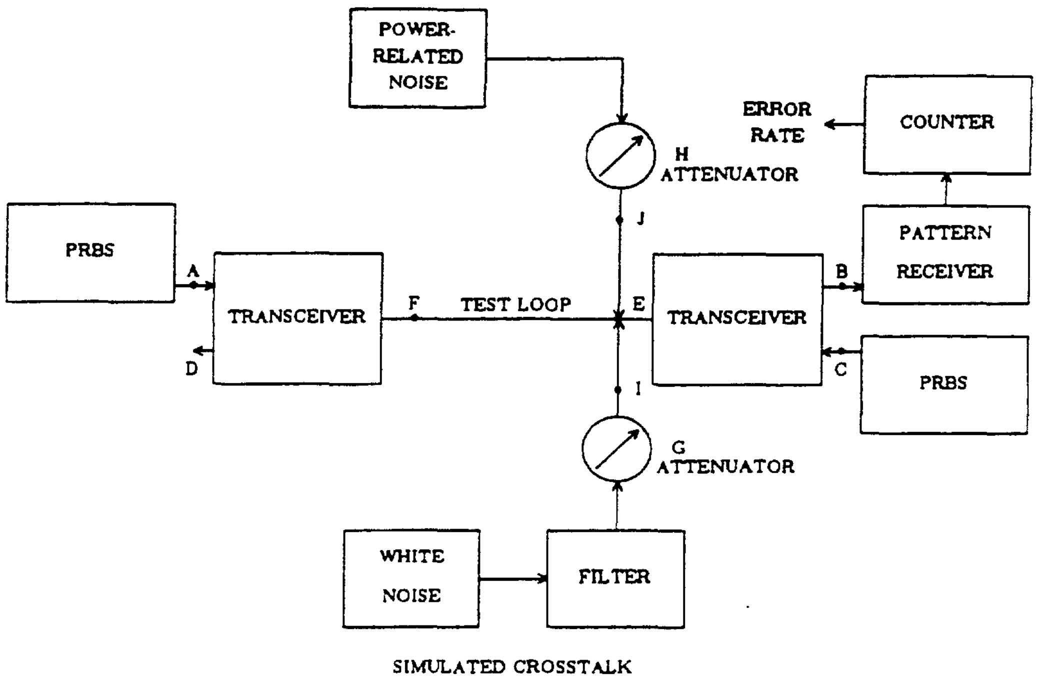
The second conceptual section, the simplified NEXT model, is a transfer function with loss decreasing at 15 dB per decade of frequency and having 57 dB loss at 80 kHz.

This transfer function results in the $f^{\frac{3}{2}}$ factor in P_{NEXT} (see C.1.1). This transfer function can not be realized as a separate filter because it exhibits a singularity at infinity. The transfer function is an approximation to the average NEXT loss for the worst 1% of pair combinations in a binder group in the population of all binder groups (see Section 4.1).

The problem of a singularity at infinity is moot because the complete filter includes a third conceptual section to bandlimit the simulated NEXT at four times the baud rate (320 kHz).

The electronic components that produce the artificial NEXT must permit the Gaussian signal to have unclipped peaks to at least six times its root mean squared value.

The NEXT source defined in Section C.1.1 is used by connecting it in parallel with the connection of the Loop to the transceiver.



Key to Labels:

- A Far End Transceiver Binary Input
- B Near End Transceiver Binary Output
- C Near End Transceiver Binary Input
- D Far End Transceiver Binary Output
- E Near End Transceiver Interface (Noise Sum Point)
- F Far End Transceiver Interface (Not Under Test)
- G Attenuator for Calibration of Simulated NEXT
- H Attenuator for Calibration of Power-Related Noise
- I High-Impedance Coupling Circuit for Simulated NEXT
- J High-Impedance Coupling Circuit for Power-Related Noise

Figure C-1
Laboratory Test Set-Up for Measuring BER

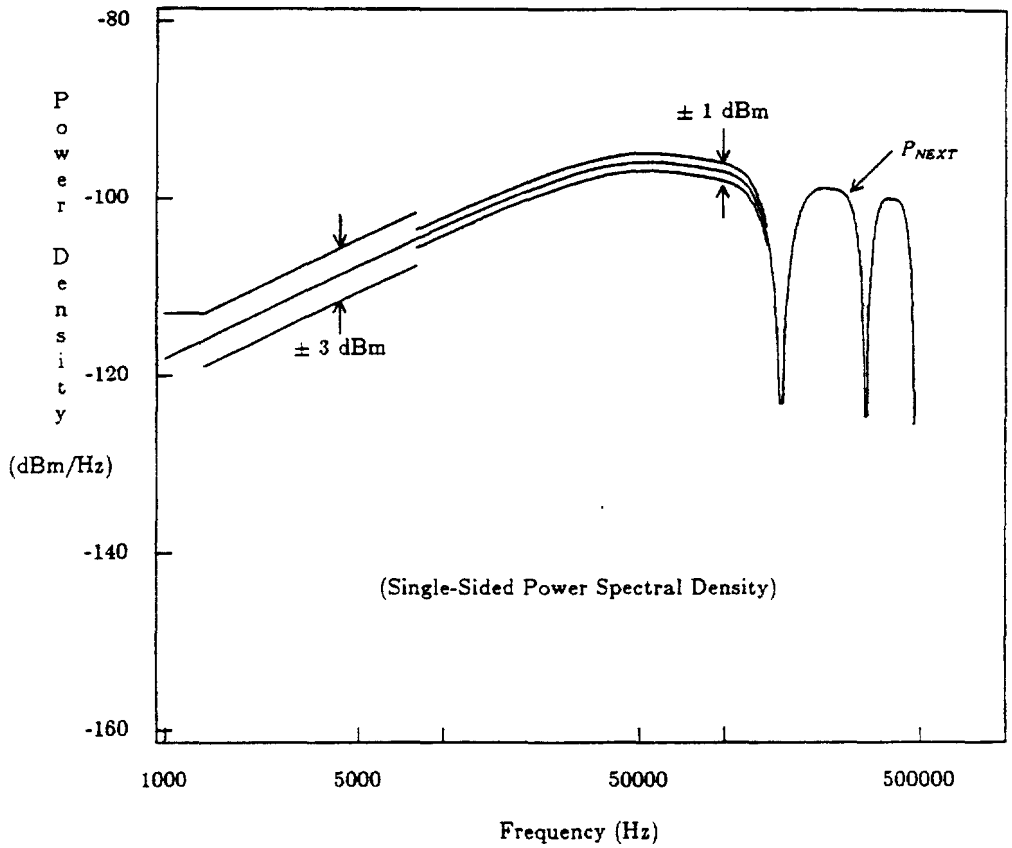
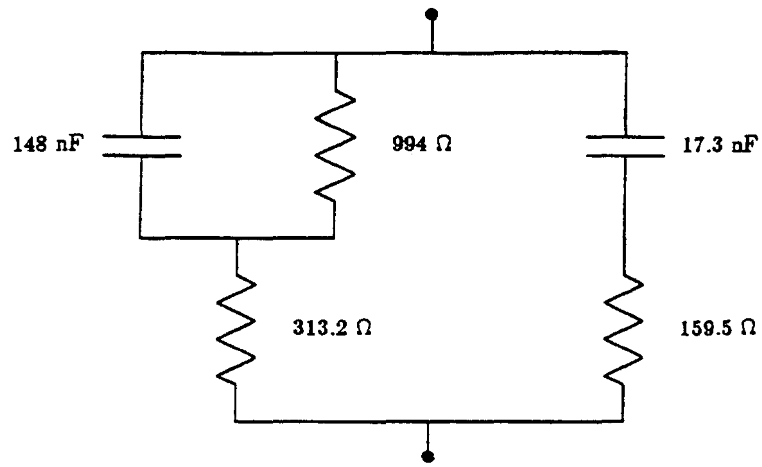


Figure C-2
PSD for Simulated Near End Crosstalk (NEXT) for Testing 2B1Q System



NOTE: Component tolerances ±1%.

Figure C-3
Crosstalk Calibration Impedance, Z_c

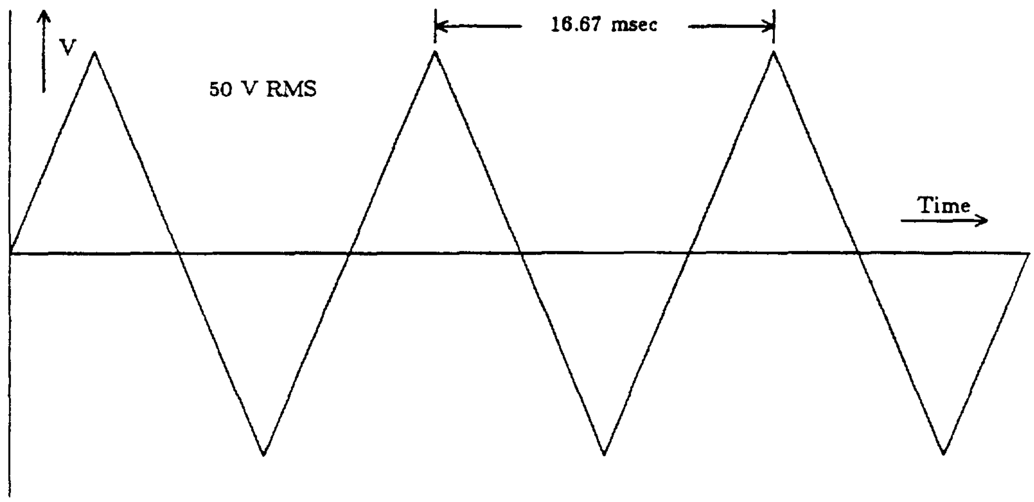


Figure C-4
Waveform for Longitudinal Noise

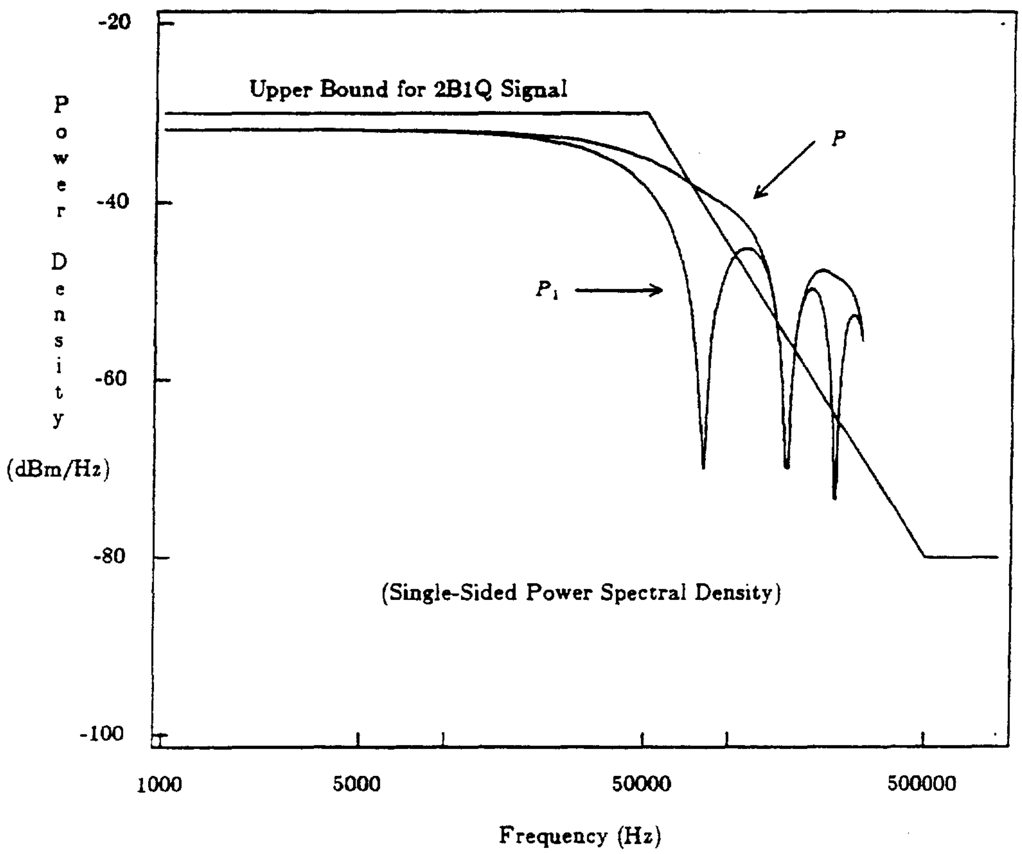


Figure C-5
Power Spectral Density (PSD) of Assumed Interferers

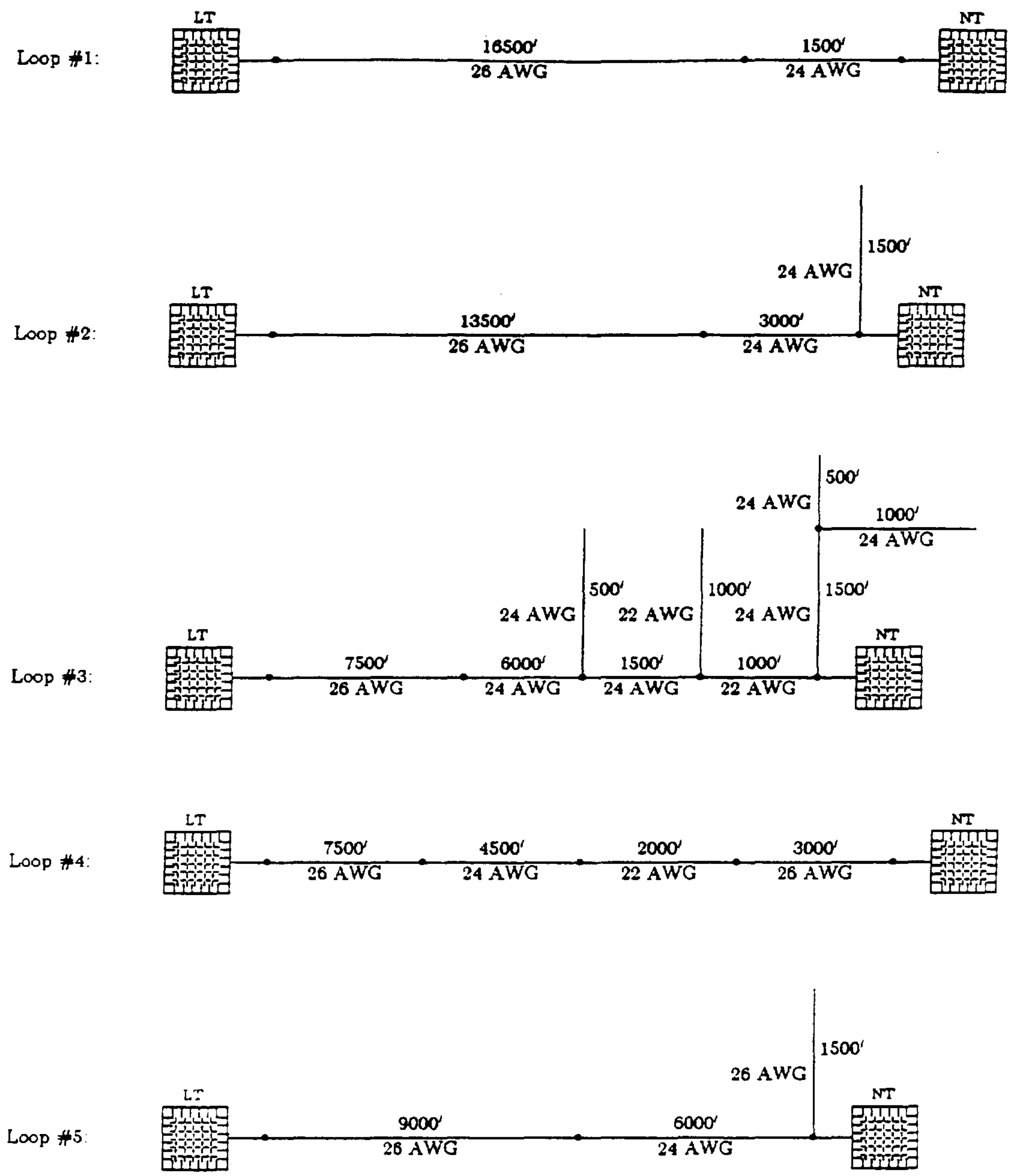
APPENDIX D

SUBSCRIBER LOOPS FOR TESTING BER

The cable make-ups of 15 loops to be used in the measurement of BER are given in Figure D-1. These loops were chosen with the help of loop configurations found in the 1983 Loop Survey[6] database. However, the actual loop make-ups, as found in the Survey, have been somewhat simplified to make it easier to simulate these loops in a laboratory. Thus, the sections of different gauge are relatively long, and in multiples of a convenient length in kilofeet. The units "kilofeet" and "gauge" are used to conform to records for most existing Bell Operating Company plant.

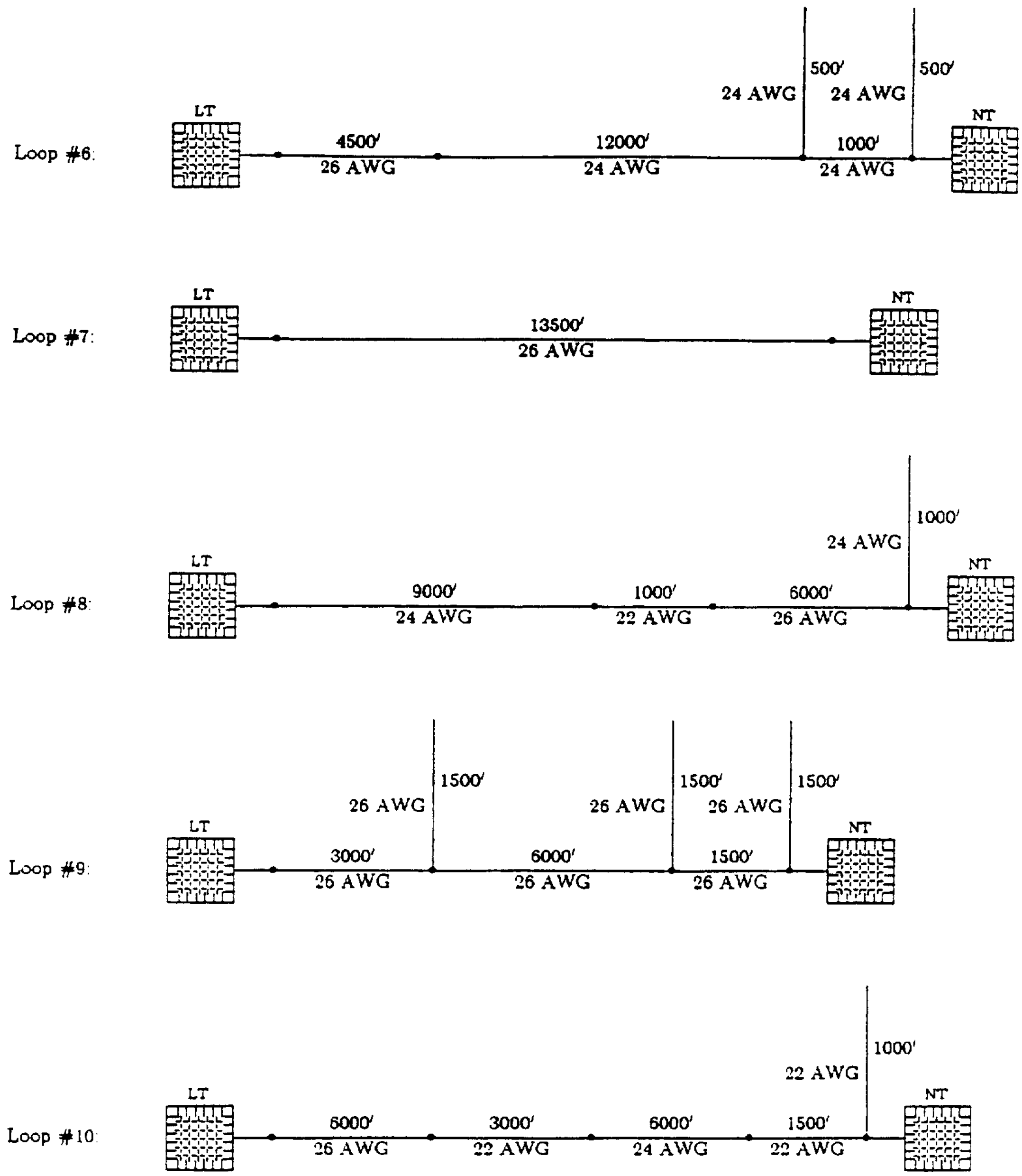
The fifteen test loops were chosen from a set of 300 loops in the 1983 Loop Survey that showed the greatest mean square loss for transmission with the 2B1Q line code. The characteristics of the test loops are defined over a broad frequency range by means of the primary constants listed in Tables D-1, D-2, and D-3. The tables give values of resistance per mile (R), inductance per mile (L), conductance per mile (G), and capacitance per mile (C) based on a commonly used model of polyethelene insulated cable (PIC) at 70 ° F. Actual cable deviates from the precise model, depending on such factors as temperature, insulation type, manufacturer, and detailed manufacturing conditions.

In theoretical calculations by Bell Communications Research, there was found to be a tight monotonic relationship between mean square insertion loss and system signal to noise ratio when the mean square loss was greater than about 20 dB. This implies that there is a correlation between mean square insertion loss and system performance at high loss. Thus, the fifteen loops presented here will stress the DSL by simulating operation near the limit of loop transmission characteristics.



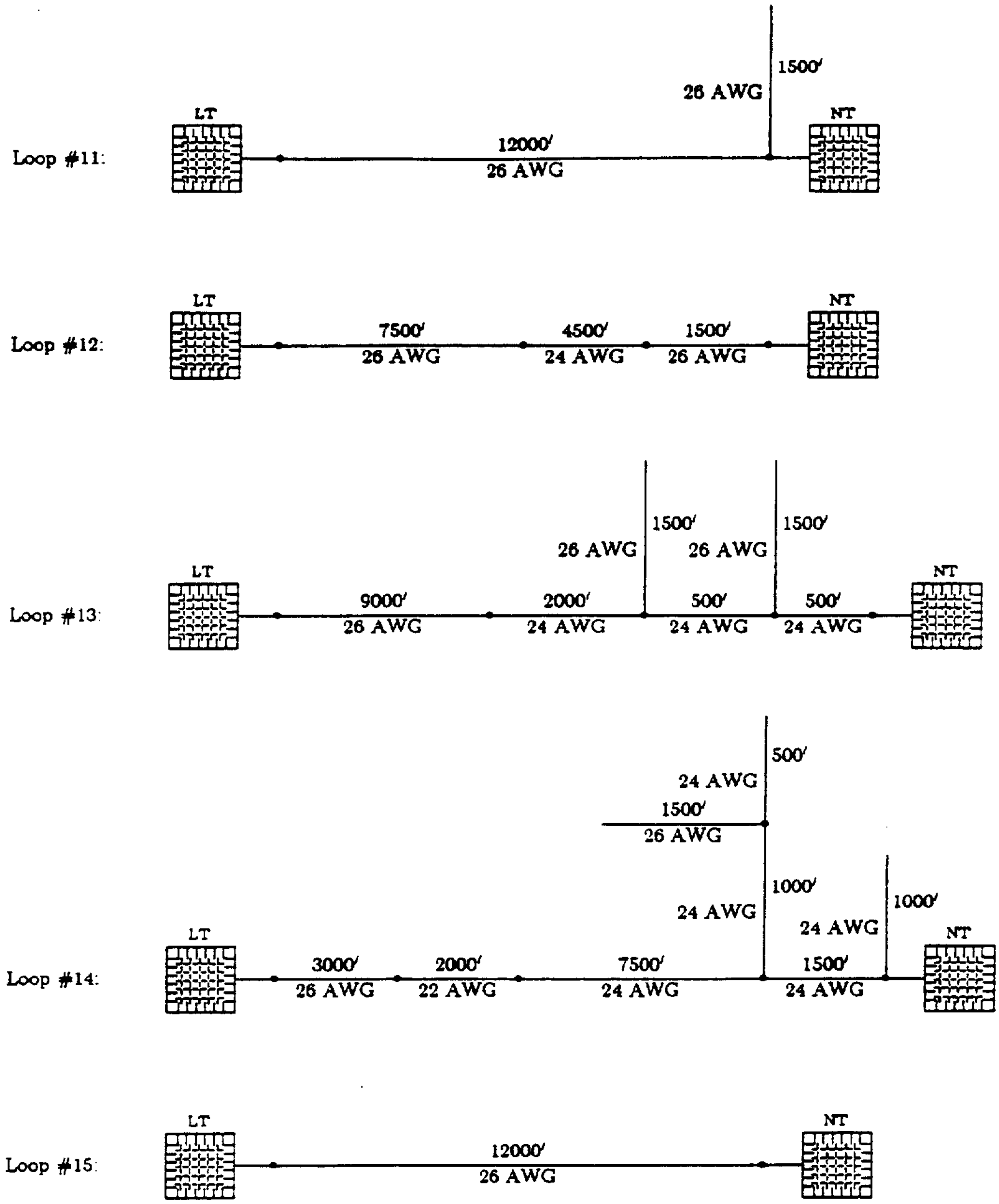
Note: 1) AWG means American Wire Gauge
2) Distances are in feet (′): 1000′ = .3048 km

Figure D-1a
Loops for Testing Received Signal Performance: #1 - #5



Note: 1) AWG means American Wire Gauge
2) Distances are in feet ('): 1000' = .3048 km

Figure D-1b
Loops for Testing Received Signal Performance: #6 - #10



Note: 1) AWG means American Wire Gauge
2) Distances are in feet (′): 1000′ = .3048 km

Figure D-1c
Loops for Testing Received Signal Performance: #11 - #15

Table D-1
26 AWG PIC Cable at 70°F

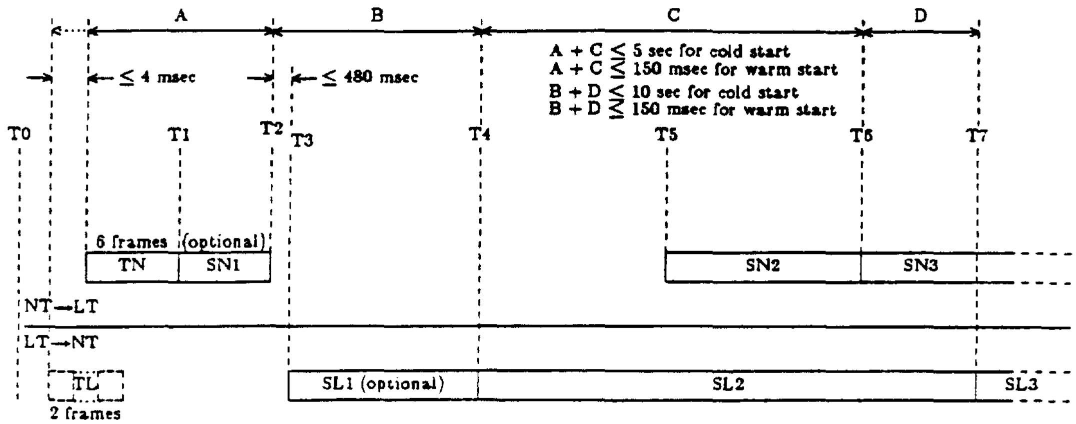
	Primary Constants 1 Hz to 5 MHz			
Freq (Hz)	R (Ohms/mi)	L (mH/mi)	G (μmho/mi)	C (μF/mi)
1.	440.75	0.9861	0.000	0.08300
5.	440.75	0.9861	0.001	0.08300
10.	440.75	0.9861	0.002	0.08300
15.	440.76	0.9861	0.003	0.08300
20.	440.76	0.9861	0.004	0.08300
30.	440.76	0.9861	0.005	0.08300
50.	440.76	0.9861	0.008	0.08300
70.	440.76	0.9861	0.011	0.08300
100.	440.76	0.9861	0.016	0.08300
150.	440.76	0.9861	0.022	0.08300
200.	440.76	0.9860	0.028	0.08300
300.	440.76	0.9660	0.040	0.08300
500.	440.77	0.9859	0.063	0.08300
700.	440.78	0.9859	0.084	0.08300
1,000.	440.79	0.9858	0.115	0.08300
1,500.	440.81	0.9856	0.164	0.08300
2,000.	440.83	0.9854	0.210	0.08300
3,000.	440.88	0.9850	0.299	0.08300
5,000.	441.01	0.9843	0.466	0.08300
7,000.	441.15	0.9836	0.625	0.08300
10,000.	441.39	0.9825	0.853	0.08300
15,000.	441.87	0.9807	1.213	0.08300
20,000.	442.88	0.9789	1.558	0.08300
30,000.	443.88	0.9753	2.217	0.08300
50,000.	447.81	0.9660	3.458	0.08300
70,000.	453.09	0.9546	4.634	0.08300
100,000.	463.39	0.9432	6.320	0.08300
150,000.	485.80	0.9306	8.993	0.08300
200,000.	513.04	0.9212	11.550	0.08300
300,000.	575.17	0.9062	16.436	0.08300
500,000.	699.61	0.8816	25.633	0.08300
700,000.	812.95	0.8614	34.351	0.08300
1,000,000.	956.65	0.8381	46.849	0.08300
1,500,000.	1154.38	0.8146	66.665	0.08300
2,000,000.	1321.07	0.8001	85.624	0.08300
3,000,000.	1600.68	0.7823	121.841	0.08300
5,000,000.	2044.07	0.7638	190.021	0.08300

Table D-2
24 AWG PIC Cable at 70 °F

	Primary Constants 1 Hz to 5 MHz			
Freq (Hz)	R (Ohms/mi)	L (mH/mi)	G (μmho/mi)	C (μF/mi)
1.	277.19	0.9861	0.000	0.08300
5.	277.19	0.9861	0.001	0.08300
10.	277.19	0.9861	0.002	0.08300
15.	277.19	0.9861	0.003	0.08300
20.	277.19	0.9861	0.004	0.08300
30.	277.19	0.9861	0.005	0.08300
50.	277.19	0.9861	0.008	0.08300
70.	277.19	0.9861	0.011	0.08300
100.	277.19	0.9861	0.016	0.08300
150.	277.20	0.9860	0.022	0.08300
200.	277.20	0.9860	0.028	0.08300
300.	277.20	0.9860	0.040	0.08300
500.	277.21	0.9859	0.063	0.08300
700.	277.22	0.9858	0.084	0.08300
1,000.	277.23	0.9857	0.115	0.08300
1,500.	277.25	0.9854	0.164	0.08300
2,000.	277.28	0.9852	0.210	0.08300
3,000.	277.34	0.9848	0.299	0.08300
5,000.	277.48	0.9839	0.466	0.08300
7,000.	277.66	0.9829	0.625	0.08300
10,000.	277.96	0.9816	0.853	0.08300
15,000.	278.58	0.9793	1.213	0.08300
20,000.	279.35	0.9770	1.558	0.08300
30,000.	281.30	0.9723	2.217	0.08300
50,000.	286.82	0.9577	3.458	0.08300
70,000.	294.29	0.9464	4.634	0.08300
100,000.	308.41	0.9347	6.320	0.08300
150,000.	337.22	0.9204	8.993	0.08300
200,000.	369.03	0.9087	11.550	0.08300
300,000.	431.55	0.8885	16.436	0.08300
500,000.	541.69	0.8570	25.633	0.08300
700,000.	632.08	0.8350	34.351	0.08300
1,000,000.	746.04	0.8146	46.849	0.08300
1,500,000.	902.84	0.7947	66.665	0.08300
2,000,000.	1035.03	0.7825	85.624	0.08300
3,000,000.	1256.77	0.7676	121.841	0.08300
5,000,000.	1608.38	0.7523	190.021	0.08300

Table D-3
22 AWG PIC Cable at 70 °F

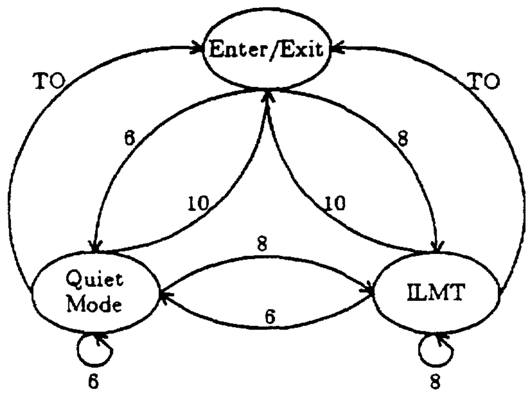
	Primary Constants 1 Hz to 5 MHz			
Freq (Hz)	R (Ohms/mi)	L (mH/mi)	G (μmho/mi)	C (μF/mi)
1.	174.27	0.9861	0.000	0.08300
5.	174.27	0.9861	0.001	0.08300
10.	174.27	0.9861	0.001	0.08300
15.	174.27	0.9861	0.001	0.08300
20.	174.27	0.9861	0.002	0.08300
30.	174.27	0.9861	0.003	0.08300
50.	174.27	0.9861	0.005	0.08300
70.	174.27	0.9861	0.006	0.08300
100.	174.27	0.9861	0.009	0.08300
150.	174.27	0.9860	0.013	0.08300
200.	174.27	0.9860	0.017	0.08300
300.	174.28	0.9860	0.024	0.08300
500.	174.29	0.9858	0.040	0.08300
700.	174.29	0.9857	0.054	0.08300
1,000.	174.31	0.9856	0.076	0.08300
1,500.	174.34	0.9853	0.110	0.08300
2,000.	174.37	0.9850	0.145	0.08300
3,000.	174.44	0.9844	0.211	0.08300
5,000.	174.62	0.9833	0.341	0.08300
7,000.	174.83	0.9821	0.467	0.08300
10,000.	175.22	0.9804	0.652	0.08300
15,000.	176.06	0.9778	0.954	0.08300
20,000.	177.11	0.9744	1.248	0.08300
30,000.	179.86	0.9672	1.824	0.08300
50,000.	187.64	0.9491	2.943	0.08300
70,000.	197.71	0.9372	4.032	0.08300
100,000.	215.55	0.9237	5.630	0.08300
150,000.	247.57	0.9055	8.229	0.08300
200,000.	277.95	0.8898	10.772	0.08300
300,000.	333.39	0.8642	15.744	0.08300
500,000.	421.57	0.8309	25.396	0.08300
700,000.	493.24	0.8123	34.796	0.08300
1,000,000.	583.59	0.7950	48.587	0.08300
1,500,000.	707.91	0.7783	71.014	0.08300
2,000,000.	812.72	0.7681	92.958	0.08300
3,000,000.	988.53	0.7557	135.865	0.08300
5,000,000.	1267.31	0.7429	219.158	0.08300



Time: Description of Event or State:

T0 RESET state.
T1 LT and NT are awake.
T2 NT discontinues transmission, indicating that the NT is ready to receive signal.
T3 LT responds to termination of signal and begins transmitting signal toward the NT.
T4 LT begins transmitting SL2 toward the NT, indicating that the LT is ready to receive SN2.
T5 NT begins transmitting SN2 toward the LT, indicating that NT has acquired SW frame and detected SL2.
T6 NT has acquired superframe marker, and is fully operational.
T7 LT has acquired superframe marker, and is fully operational.

Figure 5-12
State Sequence for DSL Transceiver Start-Up



WHERE:

ILMT = Insertion Loss Measurement Test
Insertion Loss Signal = Scrambled, framed 2B1Q
6, 8, 10 = Number of pulses within trigger signal
Trigger Signal = dc or low frequency ac pulses
TO = Timeout = 75 seconds

Note: As a result of a power off/on cycle, the NT exits the maintenance mode and attempts start-up. All knowledge of previous maintenance modes is lost.

Figure 5-13
NT Loop Testing States

6. Generic DSL Power and Interface Requirements

This section specifies the power and interface requirements of the DSL.

6.1 Power Requirements

(O) The power consumption of the transmitter and receiver of the DSL **should** not exceed 100 mW. Power requirements for equipment embodying the DSL are given in TR-NWT-000397[3].

6.2 Line Interface

(R) The interface with the tip-ring pair **shall** have the following characteristics:

6.2.1 Impedance and Return Loss

(R) The nominal driving point impedance of the equipment, when powered, looking toward the NT, **shall** be 135 Ohms.

(R) The return loss with respect to 135 Ohms, over a frequency band from 1 kHz to 200 kHz, **shall** be as shown in Figure 6-1.

6.2.2 Sealing Current

(R) If sealing current is provided by the LT, the NT **shall** meet the requirements of this specification for currents of 0 mA and in the range of 1.0 mA to 20 mA, with the maximum rate of change of the current $\leq$ 20 mA per second.

6.2.3 Metallic Termination

The metallic termination provides a direct current path from tip to ring at the NT, providing a path for sealing current. By exercising the nonlinear functions of the metallic termination, a network-side test system may identify the presence of a conforming NT on the customer side of the interface.

(R) The characteristics of the metallic termination **shall** not be affected by whether the NT is powered in any state, or unpowered.

There are two operational states of the dc metallic termination; (1) the ON or conductive state and (2) the OFF or non-conductive state.

6.2.3.1 ON State

(R) The application of a voltage across the metallic termination greater than the activate/non-activate voltage, V_{AN}, for a duration greater than the activate time **shall** cause the termination to transition to the ON state. The activate/non-activate voltage **shall** be in the range of 30.0 volts to 39.0 volts. The activate time **shall** be in the range of 3.0 ms to 50.0 ms. If a change of state is to occur, the transition **shall** be completed within 50.0 ms from the point where the applied voltage across the termination first exceeds V_{AN}. Application of a voltage greater than the V_{AN} for a duration less than 3.0 ms **shall** not cause the termination to transition to the ON state. See Table 6-1 and Figure 6-2.

(R) While in the ON state, when the voltage across the termination is 15.0 volts, the current **shall** be greater than or equal to 20 mA. The metallic termination **shall** remain in the ON state as long as the current is greater than the threshold I_{HR} whose value **shall** be in the range of 0.1 mA to 1.0 mA. Application of 90.0 volts through

200 to 4000 Ohms (for a maximum duration of 2 seconds) **shall** result in a current greater than 9.0 mA. See Table 6-1 and Figure 6-2.

6.2.3.2 OFF State

(R) The metallic termination **shall** transition to the OFF state if the current falls below the threshold I_{HR} whose value **shall** be in the range of 0.1 mA and 1.0 mA for a duration greater than the "guaranteed release" time (100.0 ms). If a change of state is to occur, the transition **shall** be completed within 100.0 ms from the point where the current first falls below I_{HR}. If the current falls below I_{HR} for a duration less than 3.0 ms the termination **shall** not transition to the OFF state. See Table 6-1 and Figure 6-2.

(R) While in the OFF state, the current **shall** be less than 5.0 μA whenever the voltage is less than 20.0 volts. The current **shall** not exceed 1.0 mA while the voltage across the termination remains less than the activate voltage.

Table 6-1 and Figure 6-2 provide characteristics that apply to the dc metallic termination of the NT.

6.2.3.3 NT Capacitance

(R) While the metallic termination if OFF, the tip to ring capacitance of the NT when measured at a frequency of less than 100 Hz **shall** be 1.0 μF $\pm$10%.

6.2.4 Behavior of the NT during Metallic Testing

During metallic testing, the NT shall behave as follows:

(R)

(1) When a test voltage of up to 90 volts[4] is applied across the loop under test, the NT **shall** present its dc metallic termination as defined in 6.2.3, Table 6-1 and Figure 6-2, and not trigger any protective device that will mask this signature. The series resistance (test system + test trunk + loop + margin) can be from 200 to 4000 ohms (balanced between the two conductors).

(2) The NT may optionally limit current excess of 25 mA (20 mA maximum sealing current + 5 mA implementation margin).

6.2.5 NT Network Side Resistance to Ground

(R) The dc resistance between the NT's tip conductor and earth ground and between the NT's ring conductor and earth ground **shall** be greater than 5 Megaohms for all dc voltages up to and including 100 volts.

6.2.6 Longitudinal Output Voltage

(R) The NT and LT **shall** present to the interface a longitudinal component whose rms voltage, in any 4 kHz bandwidth averaged in any 1 second period, is less than −50 dBV over the frequency range 100 Hz to 170 kHz, and less than −80 dBV over the range from 170 kHz to 270 kHz. Compliance with this limitation is required with a

4. One test system in common use today applies a 70 volts dc plus 10 volts rms ac (84.4 volts peak) to one conductor of the loop while grounding the other conductor. The addition of a 5.8 volt margin yields the 90 volt requirement

longitudinal termination having an impedance equal to or greater than a 100 Ohm resistor in series with a 0.15 μF capacitor.

(O) Figure 6-3 defines a measurement method for longitudinal output voltage. For direct use of this test configuration, the near end transmitter **should** be able to generate a signal in the absence of a signal from the far end transceiver.

(R) The ground reference for these measurements **shall** be the building or green wire ground.

6.2.7 NT Longitudinal Balance

The longitudinal balance (impedance to ground) is given in the equation below:

$$LBal = 20 \log \left| \frac{e_l}{e_m} \right| dB$$

where

e_l = the applied longitudinal voltage (referenced to the building or green wire ground of the NT)

e_m = the resultant metallic voltage appearing across a 135 Ohm termination.

(R) The NT longitudinal balance **shall** be as shown in Figure 6-4.

(O) Figure 6-5 defines a measurement method for longitudinal balance. For direct use of this test configuration, measurement **should** be performed with the transceiver powered up but inactive, driving zero volts.

6.2.8 LT Longitudinal Balance

(R) LT longitudinal balance **shall** be defined as in section 6.2.5.

(R) The LT longitudinal balance **shall** be as shown in Figure 6-6.

(O) Procedures for measuring LT longitudinal balance is defined in Figure 6-5.

6.2.9 Electrical Protection

Criteria intended to establish the immunity of the LT, LULT and NT to damage and fire hazard from lightning surges and AC power fault conditions that may be encountered on the network are contained in TR-TSY-000499[17]. Secondary protection that is provided as part of the DSL for customer premises mounted equipment must conform to the impedance and longitudinal signal requirements stated above, as well as the electrical protection considerations contained in Section 14.2.10 of TR-TSY-000499[17].

6.2.10 Electrostatic Discharge

(R) The LT, LULT and NT **shall** meet the electrostatic discharge criteria of TR-EOP-00063[18].

6.2.11 Electrical Safety

(R) The LT, LULT and NT **shall** meet the electrical safety criteria of TR-TSY-000499[17], Section 14.5.

Table 6-1
Characteristics of DC Metallic Termination in the NT

Type of Operation:	Normally OFF DC termination. Turn ON by application of metallic voltage. Held ON by loop current flow. Turned OFF by cessation of loop current flow.
Current in the ON state and at 15 V :	$\geq$ 20 mA
DC voltage drop (when ON) at 20 mA current :	$\leq$ 15 V
DC current, with the application of 90 V through 4000 Ohms for up to 2 seconds :	min 9 mA† (See Figure 6-2)
DC leakage current (when OFF) at 20 V :	$\leq$ 5.0 μA
Activate/Non-Activate voltage :	30.0 V DC $\leq V_{AN} \leq$ 39.0 V DC
Hold/Release current :	0.1 $mA \leq I_{HR} \leq$ 1.0 mA
Activate (Breakover) current at V_{AN} :	$\leq$ 1.0 mA
Activate time for voltage $\geq V_{AN}$:	3 msec to 50 msec
Release/Non-Release time for current $\leq I_{HR}$:	3 msec to 100 msec

†This requirement is intended to ensure a termination consistent with test system operation.

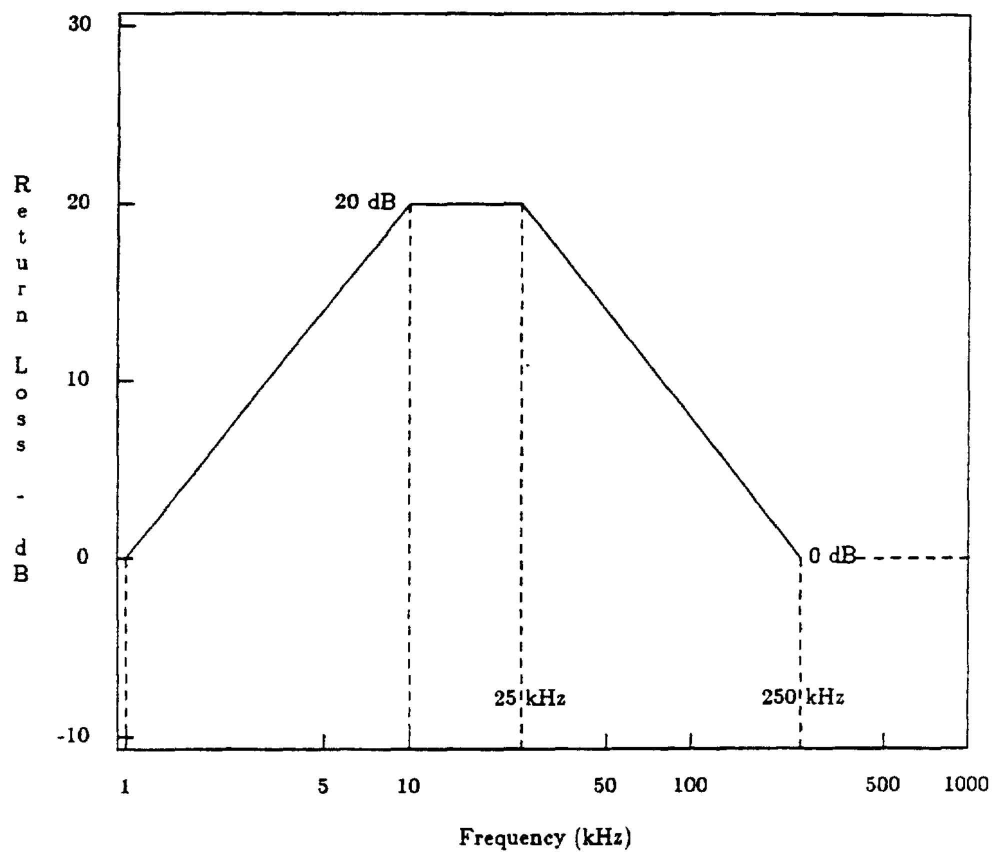
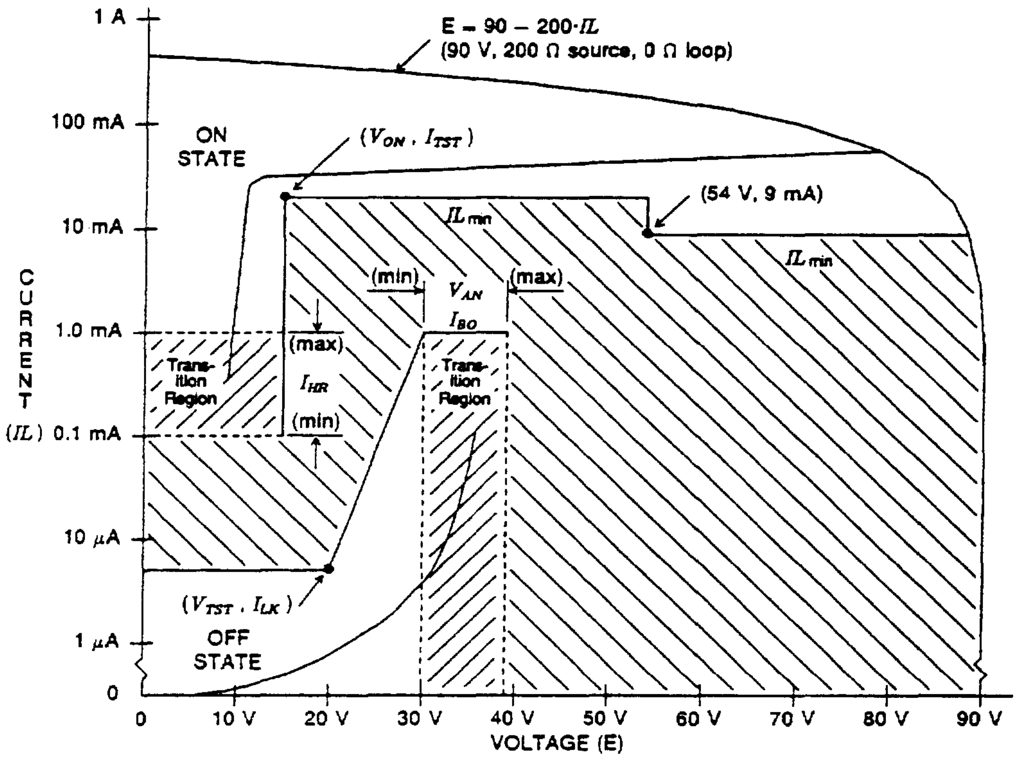


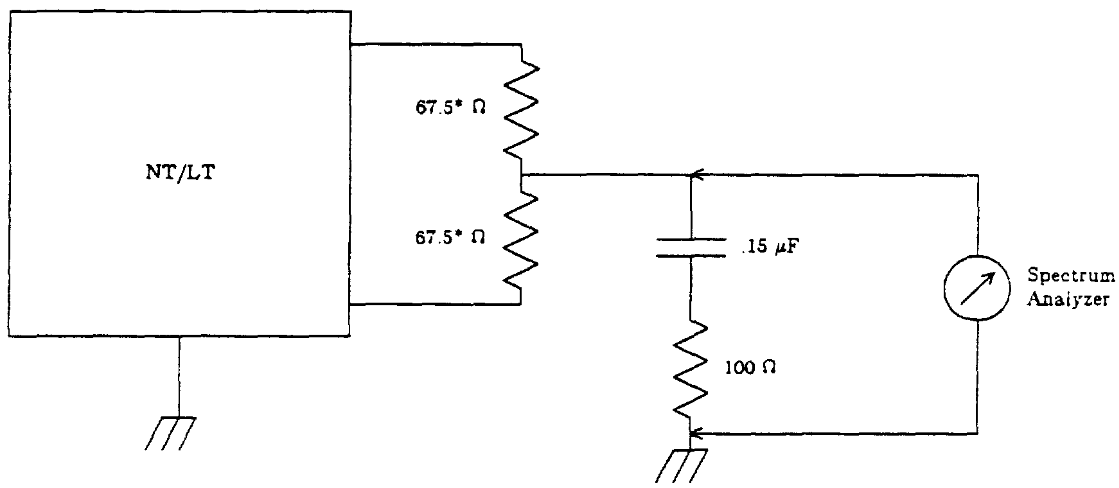
Figure 6-1
Minimum Return Loss



DC CHARACTERISTICS (EITHER POLARITY)

PARAMETER	MEANING	LIMIT	CONDITION	MEANING
I_{LK}	Leakage Current	$I_{LK} \leq 5\ \mu A$	$V_{TST} = 20$ V	Test Voltage
V_{AN}	Activate/Non-Activate Voltage	$30\ V \leq V_{AN} \leq 39\ V$		
I_{BO}	Break Over Current	$I_{BO} \leq 1.0$ mA		
I_{HR}	Hold/Release Current	$0.1\ mA \leq I_{HR} \leq 1.0$ mA		
V_{ON}	ON Voltage	$V_{ON} \leq 15$ V	$I_{TST} = 20$ mA	Test current
IL_{min}	Minimum ON Current	9 mA	54 V	

Figure 6-2
Illustration of dc Characteristics of the NT
(bilateral switch and holding current)



* These resistors matched to a better than 0.1% tolerance.

Figure 6-3
Measurement Method for Longitudinal Output Voltage

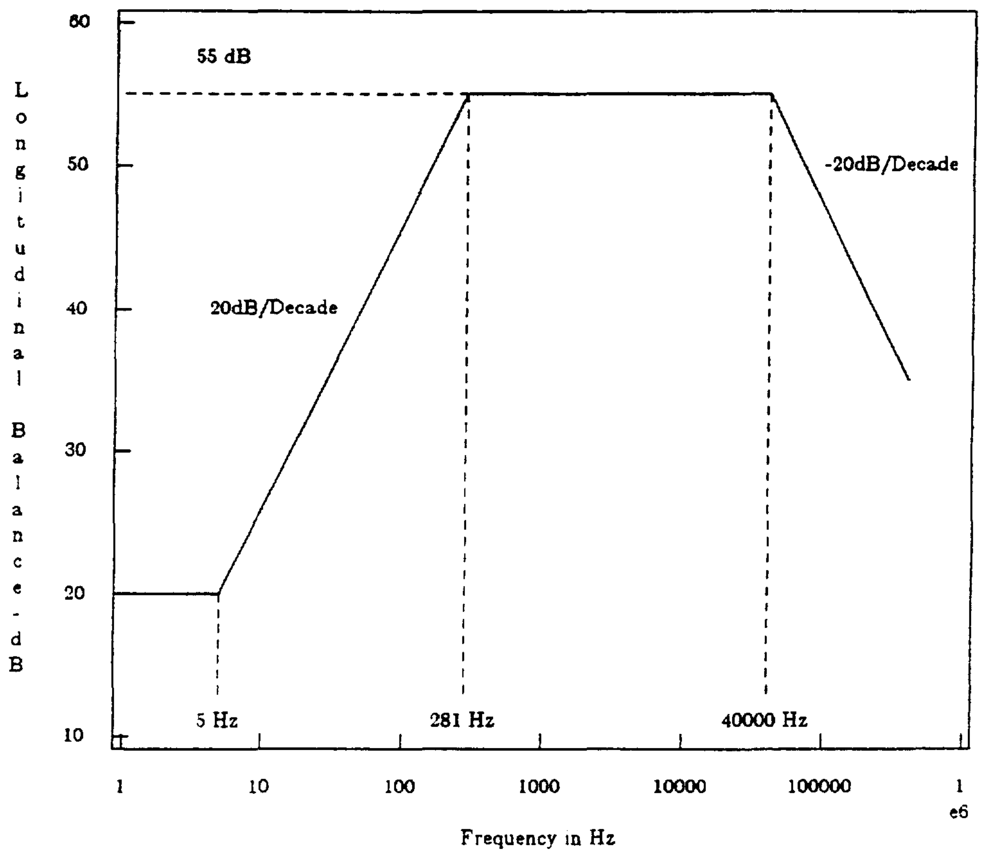
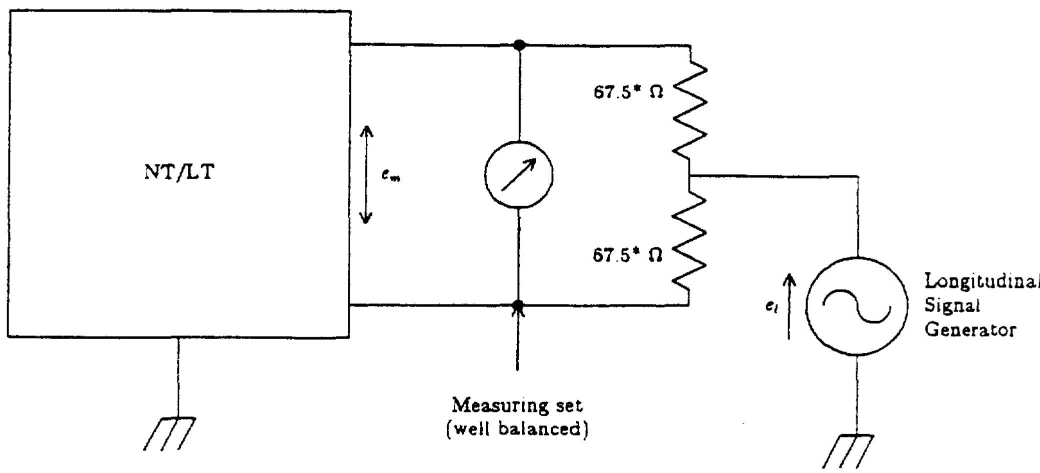


Figure 6-4 NT-Longitudinal Balance



* These resistors to be matched to better that 0.03% tolerance

Figure 6-5
Measurement Method for Longitudinal Balance

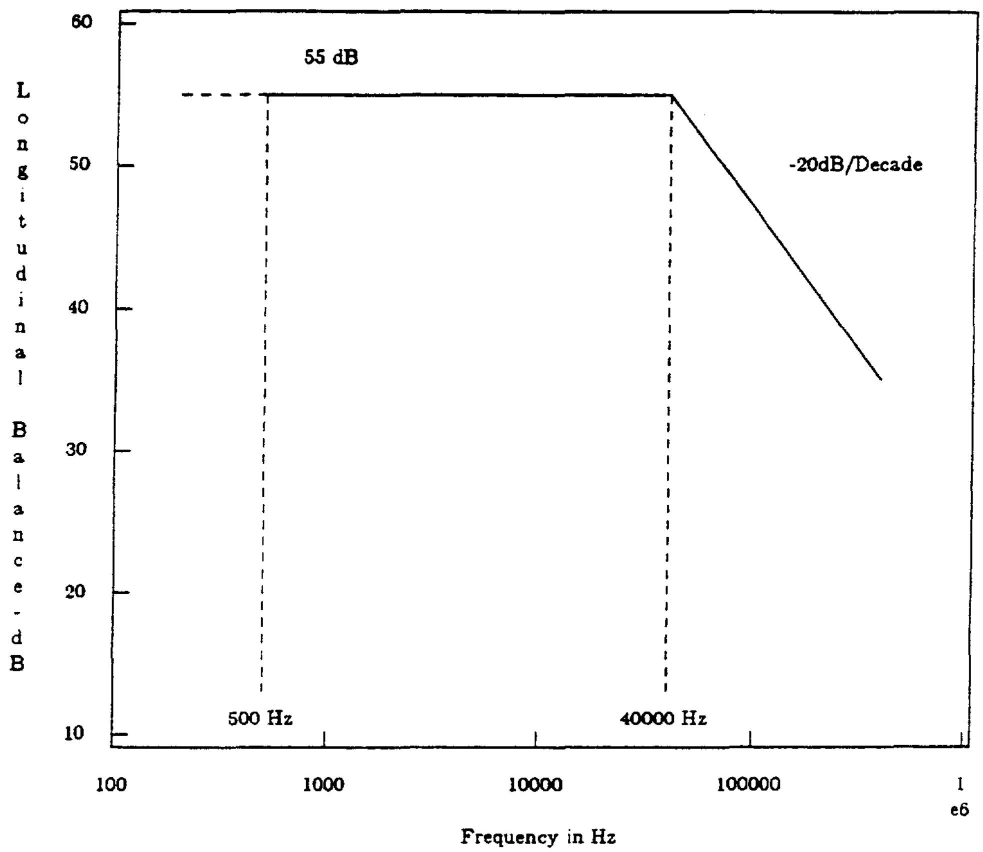


Figure 6-8 LT-Longitudinal Balance

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APPENDIX A
GLOSSARY

2B1Q — 2 Binary, 1 Quaternary - A line code in which each two bits of the binary data stream are combined into a single symbol of the quaternary line signal.

ADM — Add-Drop Multiplexer - A device that allows individual channels to be inserted or removed from a multiplexed signal.

Basic Access — A term used to describe a simple standardized combination of access channels that constitute the access arrangements for the majority of ISDN users; specifically, any of the following combinations of access channels:
(1) One D channel
(2) One B channel plus one D channel
(3) Two B channel plus one D channel

B Channel — A 64 kbit/s channel that carries customer information such as voice calls, circuit-switched data, or packet-switched data.

BER — Bit Error Ratio - The ratio of the number of errors in the received signal to the number of bits transmitted.

CCITT — International Telegraph and Telephone Consultative Committee - The International Telecommunication Union (ITU) is a specialized agency of the United Nations (since 1948) and is an international treaty organization. It traces its formal beginnings to 1865. The International Telegraph and Telephone Consultative Committee (CCITT) is one of 7 ITU organizations. CCITT has responsibility for standards work done in the ITU. The general purpose of the CCITT is to promote and ensure the operation of international telecommunications systems.

crc — Cyclic Redundancy Check - A procedure used to detect the correct transmission of a block of data by performing a known mathematical operation on the data at the transmitter and comparing the result with the same operation performed at the receiver.

Crosstalk	The unwanted transfer of energy from one working circuit to another working circuit.
D Channel	An access channel carrying control or signaling information and, optionally, packetized information and telemetry. When a part of Basic Access, the D channel has a capacity of 16 kbit/s.
DLC	Digital Loop Carrier - A transmission system in which signals from multiple users are multiplexed and digitally transmitted over loop plant cables.
DSL	Digital Subscriber Line - A technology that provides full-duplex service on a single twisted metallic pair at a rate sufficient to support ISDN Basic Access and additional framing, timing recovery and operations functions. The physical termination of the DSL at the network end is the LT; the physical termination at the user end is the NT.
Echo Cancellation	A technique for implementing a DSL in which a record of the transmitted signal is used to remove echoes of this signal that may have mixed with and corrupted the received signal.
eoc	Embedded Operation Channel - A channel, separate from the customer's B and D channels, used to carry operations information in ISDN Basic Access.
febe	Far End Block Error - A bit in the maintenance and operations channel of a DSL that is used by the NT to indicate to the LT that a block was received in error, and by the LT to indicate the same to the NT.
FEXT	Far-End Crosstalk - Crosstalk in which the interfering circuit and the interfered circuit are both transmitting in the same direction.
Full-Duplex	A method of operating a communications circuit so that each end can simultaneously transmit and receive.
Interface Point	The location of the interface of the access line with the NT, commonly called the U-interface. The location of the interface shall be on the customer's premises at a location mutually agreed upon by the telephone company or administration and the customer.

ISDN	Integrated Digital Services Networks. An ISDN provides a wide range of voice and non-voice services within the same network using a limited set of connection types and multi-purpose user-network interface arrangements. A variety of implementation configurations is supported, including circuit-switched, packet-switched, and non-switched connections and their concatenations. New services are arranged to be compatible with 64 kbit/s switched digital connections. Service features, maintenance capabilities, and network management functions are provided through intelligence built into the network and compatible intelligence in the user terminals.
LT	Equipment that terminates the access line at the network end.
Network or Network Side	The terms Network and Network Side are used in this TR to refer to the network side of the interface or the network functions as seen from the interface.
NEXT	Near-End Crosstalk - Crosstalk in which the interfering circuit and the interfered circuit are transmitting in different directions.
NT	The term NT is used in this TR to refer to equipment that terminates the DSL on the customer side of the interface. The NT function may be in an NT1, and NT2, or a TE. An NT1 is a network termination of an access line that provides minimal physical layer functionality. An NT2 is a network termination with functionality that can include interfacing higher layer protocols. A TE is customer terminal equipment, e.g. a computer terminal, and may include network termination functions.
OSI	Open Systems Interconnection - A communications architecture developed by the International Organization for Standardization (ISO), in which the communications process is divided into layers. Layer 1 (Physical) is concerned with the physical connection to the communications medium.
ppm	parts per million

PRBS

Pseudo-Random Binary Sequence - A sequence of binary digits generated by an algorithm such that the statistical properties of the sequence approach that of a truly random sequence. As the sequence is the result of executing an algorithm, it can be reproduced exactly at different times, and at different places. Furthermore, due to the nature of finite-state machines, the sequence must repeat itself after a certain number of bits have been generated; hence, the term "pseudo"-random.

Stratum 4

In Telephone Company synchronization plans, the level of synchronization corresponding to the least stable frequency standard. A Stratum 1 clock corresponds to the primary frequency standard; other clocks that are less stable and that are capable of following the frequency excursions of the Stratum 1 clock are designated Stratum 2, Stratum 3, and Stratum 4, in order of decreasing accuracy and stability.

MESSAGE
Subject: FW: DISC*S ISDN Application
Creator: stephw /Internet (stephw@covad.com)

Dated: 8/17/99 at 17:39
Contents: 3

Item 3.1

FROM: stephw /Internet (stephw@covad.com)
TO: THOMAS DUTTERA /m3,mail3a

Item 3.2

ARPA MESSAGE HEADER

Item 3.3

This memo is to confirm the results of the interoperability testing with the RELTEC/Marconi DISC*S Digital Loop Carrier 3 DS0 ISDN application (SCU13 channel unit) when used with Nokia Speedlink product. The testing was initiated
by USWest through our call center in an attempt to resolve issues in a circuit
using the application. Tests in our lab indicate that in this particular application the first 4 slots of each digroup of the DISC*S channel shelf cannot
be used. The specific channels affected are 1, 2, 3, 4, 5, 6, 7, 8, 25, 26, 27,
28, 29, 30, 31, 32, 49, 50, 51, 52, 53, 54, 55, 56, 73, 74, 75, 76, 77, 78, 79,
and 80. These channels are not restricted for normal ISDN applications which do
not require the additional ISDN frame relationship of the application tested.
One approach would be to create a new TIRKS line circuit code that would administratively restrict the use of these slots in this application, however,
this approach will not be pursued by Marconi Communications.
I appreciate your help in getting the equipment and support into our lab for the
interoperability tests. If I can be of further assistance to you, please feel
free to call me.

Bill Jernigan
Product Engineering Mgr
Marconi Communications
2100 Reliance Pkwy
Bedford, TX 76021

BS 2